B0-Adjusted and Sensitivity-Encoded Spectral Localization by Imaging

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INTRODUCTION: The rapid measurement of high quality MR spectra with accurate spectral localization is highly valuable, particularly in the use of MRS in clinical studies. Metabolic alterations occur in a region or tissue-type specific (i.e., gray and white matter) manner in neurological disorders/injuries mostly from areas with non-rectangular, arbitrary-shaped lesions or anatomical boundaries. Conventional MRS with rectangular voxel (Fourier) acquisition schemes are encumbered by significantly prolonged scan time and/or low spatial resolution. Spectral Localization by Imaging (SLIM) techniques [1] achieve non-Fourier based multi-voxel spectroscopy with effective super-resolution that overcomes much of the limitations presented by conventional single-voxel MRS and Fourier based CSI. However, the basic postulate of SLIM, perfect compartmental homogeneity, is often violated in *in vivo* conditions due to residual B_0 inhomogeneity and inhomogeneous coil sensitivity or B_1 profiles of multi-channel receiver coil configurations. Violations of this premise compromise the benefits of SLIM through cross-compartmental contamination and/or signal leakage, resulting in inaccurate spectral localization. A few recently proposed techniques have promised to overcome the limitations of SLIM by correcting either B_0 or B_1 field inhomogeneities [2-4]. In this study, we expanded on these approaches by developing an advanced B_0-Adjusted and Sensitivity-Encoded (BASE)-SLIM technique that simultaneously compensates both B_0 inhomogeneity and inhomogeneous coil sensitivity for fast, reliable localization of *in vivo* MRS of gray (GM) and white matter (WM) in the human brain at 3T.

METHODS: All experiments were performed on a Siemens Skyra 3 T MR system with a 16-channel receiver RF coil. PRESS localized CSI was performed on a 2-cm thick axial slab (TR/TE = 2000/30 ms, FOV = 20 cm, matrix size = 8 x 8, and NT = 4). B_0 and coil sensitivity mappings and T_1-weighted MRI were performed for SLIM based reconstruction. A three-compartment phantom containing varying concentrations and combinations of creatine (Cr), NAA, acetate, lactate and formic acid was used to test the performance of the BASE-SLIM. In order to demonstrate the effectiveness of the BASE-SLIM technique, numerical simulation was performed on synthesized data with two dimensional gray and white matter masks generated from segmented high resolution T_1-weighted images. B_0 field inhomgeneity was generated by a linear gradient magnetic field along the y-axis (10 μT/m). Coil sensitivity inhomogeneity was generated by the calculated B_1 field profile of a circular loop coil placed at 10 cm away from the center of the brain. Both B_0 map (Fig. 1A, right) and coil sensitivity map (Fig. 1A, left) were used in synthesyzing simulated data and reconstrucing spectral data. The performance of each spectral reconstruction techniques was examined by comparing the reconstructed spectra with the input spectrum for each compartment (red and green lines).

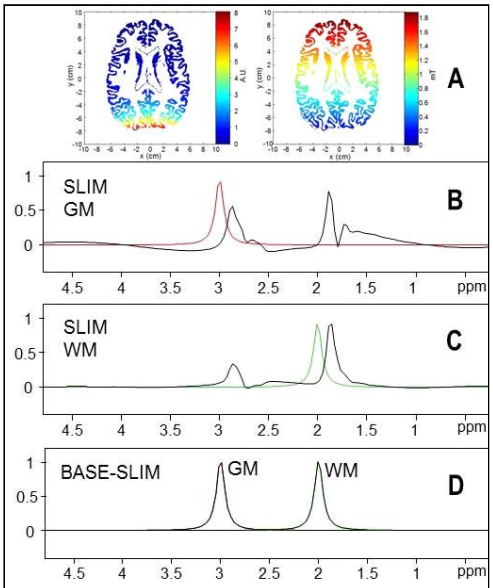

Fig. 1 Spectral reconstruction of simulated data with B_0 (A, right) and coil sensitivity (A, left) compensation (BASE-SLIM) compared with SLIM. Red, green lines: input spectra; Black: SLIM or BASE-SLIM spectra.

RESULTS AND DISCUSSION: Figure 1 shows the comparisons of localization performance of conventional SLIM and the proposed BASE-SLIM techniques on simulated data. The BASE-SLIM technique showed accurate localization of compartmental spectra in the presence of both B_0 and B_1 inhomogeneity (Fig. 1D), while SLIM showed significant inter-compartmental contaminations (Fig. 1B and 1C). Furthermore, the BASE-SLIM reconstruction showed near complete compensation of the B_0 inhomogeneity effect as shown in a complete overlap of reconstructed spectra (Fig. 1D black line) with input spectra (green and red lines) while SLIM reconstruction showed a broad, shifted, and distorted line shape (Fig. 1B and 1C). Excellent performance of the BASE-SLIM technique was demonstrated in the phantom measurement (Fig. 2). Spectra from each compartment showed unique patterns reflecting a combination of metabolites contained in each compartment, i.e., creatine, acetate, NAA, and/or lactate. Similar to the simulation outcomes, BASE-SLIM under a mis-adjusted B_0 shim along the y-axis and multi-channel receiver coils showed negligible compartmental leakage and narrower line shapes than SLIM (Fig. 2). *In vivo* spectra of gray (Fig. 3, left) and white (Fig. 3, right) matter using the BASE-SLIM (top row) show much sharper spectral linewidth compared with those using SLIM (bottom row).

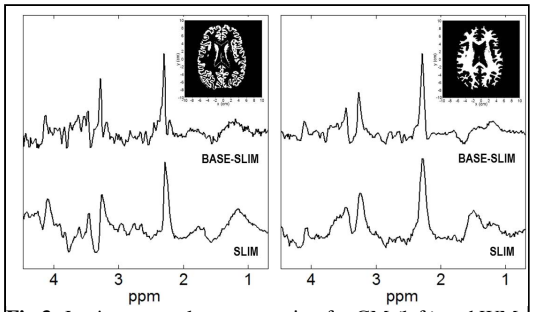

Fig 3. *In vivo* spectral reconstruction for GM (left) and WM (right panel) using the BASE-SLIM (top row) and conventional SLIM (bottom row) methods.

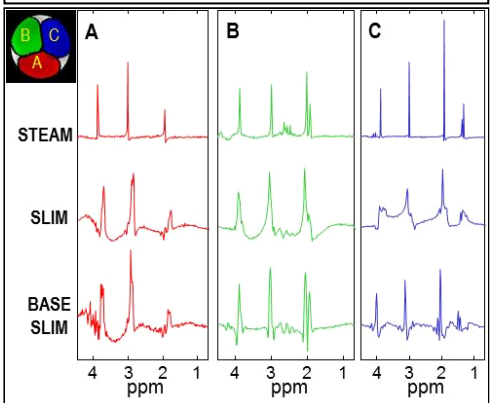

Fig 2. Spectral reconstruction of a three-compartment phantom (inset) using SLIM and BASE-SLIM.

REFERENCES: 1. Hu et al. *MRM* 8: 314 (1988). 2. Khalidov et al. *IEEE Trans Med Imaging* 26: 990 (2007). 3. Bashir et al. *MRM* 56: 7-18 (2006). 4. An et al. *MRM* 66: 1 (2011). This work is partly supported by NIH (S10RR029577) and the Hoglund Family Foundation.